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A pilot study on acoustic regulations and classification for hospitals – Comparison between the Nordic countries

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ABSTRACT

Acoustic regulations or guidelines for hospitals exist in all five Nordic countries, although with varying contents. The main purpose of limit values is to provide good acoustic conditions for the patients under treatment and for the personnel for the various tasks and activities taking place in the many different kinds of rooms in such buildings. Examples are bedrooms, examination and treatment rooms, corridors, stairwells, waiting and reception areas, dining areas, offices, all with different acoustic needs. Some of the countries specify very few acoustic limit values, while others define several criteria. Instead of or in addition to a set of regulations or guidelines, four of the Nordic countries have hospitals included in national acoustic classification standards with four acoustic quality levels A-D, class C being the regulations in three of these countries. As a pilot study, a comparison between the countries has been carried out. The paper includes examples of acoustic regulations and classification limit values for reverberation time, airborne and impact sound insulation, noise from traffic and from service equipment – aiming at discussion, potential learning and implementation of optimized limit values in acoustic regulations, guidelines or classification schemes for hospitals and other healthcare facilities.

1 INTRODUCTION

In hospitals, there is a variety of rooms with different acoustic needs, and acoustic regulations and/or acoustic quality classes or other guidelines exist in some countries, but are missing in other countries. All five Nordic countries have somehow addressed the issue, although Denmark only have a few basic limit values as recommendations, while the other four Nordic countries have extensive acoustic classification schemes including hospitals. Regulations in Norway, Sweden, Iceland are linked to the classification schemes by specifying Class C as the acoustic regulations. The Danish construction authority has decided to prepare extended acoustic guidelines for office buildings and hospitals, mainly by considering the regulations in the Nordic countries [1-5]. This paper deals with hospitals and is coordinated with another paper [6] about office buildings. The two papers have the same main structure, and parts of the introductory texts (incl. Table 1) are the same or similar.

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2 PERFORMANCE AREAS IN ACOUSTIC REGULATIONS AND GUIDELINES

In most countries in Europe, acoustic regulations now exist for housing and schools and in some countries also for other building categories like e.g. hospitals and office buildings. Acoustic regulations and classification criteria are typically about:

- Airborne sound insulation between rooms
- Impact sound insulation between rooms
- Facade sound insulation
- Service equipment noise
- Reverberation time or sound absorption

Building acoustic criteria are specified by a descriptor, a limit value, reference to a standard and sometimes to specific conditions, e.g. frequency range and/or test conditions. In Europe, most countries refer to EN ISO field measurement and rating standards, typically [7-11]. At the design stage, the acoustic performance can be estimated using prediction methods, e.g. [12-13], with relevant acoustic input data. Traffic noise may be determined according to [14].

The extent and strictness of acoustic criteria as well as descriptors in regulations and classification schemes vary considerably between countries in Europe (and globally), and it is desirable to compare such criteria and optimize by learning from other countries. Comparative studies are described in e.g. [15-18], and more references are found in [18]. Most studies are for housing and schools.

3 ACOUSTIC CLASSIFICATION SCHEMES IN EUROPE – OVERVIEW

In Table 1 is found a simplified overview of building categories in acoustic classification schemes (ACS) in Europe. It is seen that 11 countries have ACS for housing, 7 for schools, 7 for hospitals (incl. healthcare facilities) and 9 for office buildings (2 of those for office buildings only). More information about classes for hospitals and relation to regulations is found in Table 2.

Table 1 – Simplified overview of building categories in existing acoustic classification schemes in Europe.

Building categories in acoustic classification schemes in Europe – Status April 2018									
Country	Classification scheme (CS)		Dwellings	Schools	Kindergarten	Healthcare facilities	Offices	Restaurants	Other
DK	DS 490:2007	[19]	+						
FI	SFS 5907:2004	[20]	+	+	+	+	+		+
IS	IST 45:2016	[21]	+	+	+	+	+	+	+
NO	NS 8175:2012	[22]	+	+	+	+	+	+	+
SE	SS 25267:2015	[23]	+						
	SS 25268:2007	[24]		+	+	+	+	+	+
LT	STR 2.01.07:2003	[25]	+	+	+	+	(+)		+
IT	UNI 11367:2010	[26]	+	+	+	+	+		+
DE	VDI 4100:2012	[27]	+						
	DEGA 103:2018	[28]	+						
	VDI 2569:2016 Draft	[29]					+		
AT	ÖNORM B 8115-5:2012	[30]	+						
NL	NEN 1070:1999	[31]	+						
FR	NF S31-080:2006	[32]					+		
TR	Regulation on Protection of Buildings against Noise (2017)	[33]	+	+	+	+	+	+	+
ISO/WI	ISO/DIS 19488	[34]	+						

Note: The table is simplified and subject to errors due to insufficient language skills and different ways of categorizing buildings.

Table 2 – Overview quality classes for HOSPITALS in acoustic classification schemes in Europe.

Acoustic quality classes for hospitals – Europe – April 2018			
Country	Reference	Quality classes (upper class first)	Comments on classes and relation to building regulations
FI	[20]	A, B, C	Spaces not fulfilling limit values in Class C are classified as Class D, i.e. D = npd. No formal relation to the building code.
IS	[21]	A, B, C, D	For acoustic regulations, the building code refers to Class C.
NO	[22]	A, B, C, D	For acoustic regulations, the building code refers to Class C.
SE	[24]	A, B, C, D	D often = npd, i.e. no limit values. For acoustic regulations, the building code refers to Class C.
LT	[25]	B, C, D, E	For acoustic regulations, the building code refers to Class C. No limit values for reverberation time in hospital bedrooms. Limits for service equipment are found in a separate legislation.
IT	[26]	I, II, III, IV	For public hospitals, sound insulation regulations are found in [26], Annex A. However, there seems to be no "internal" limits for sound insulation, e.g. from corridors or bedrooms to the individual bedrooms.
TR	[34]	A, B, C, D, E, F	For acoustic regulations, the building code refers to Class C.
Note: Even in case of the same class denotation, e.g. C, the limit values may vary between countries.			

From Tables 1 and 2 it is seen that three countries (IS, NO, TR) have *all* building categories in *one* document and refer to Class C in the national acoustic classification scheme as the acoustic regulations, which makes it easier to get an overview of the acoustic requirements. In general, regulations are mandatory and acoustic classification voluntary, unless referred to in the regulations. In the following is focused on the Nordic countries, as was the task.

Regulations are typically for new-build only (including change of use, e.g. from a hospital building to housing). For buildings/situations/rooms not addressed in specific regulations (as is the case for healthcare facilities in Finland and Denmark), it should be noted that building regulations typically have a general statement about overall purpose. For example, in the Finnish regulations [2], it is stated that healthcare facilities etc. shall be designed and constructed, so satisfactory acoustic conditions are obtained, considering the activities. In the Danish regulations [1], the chapter about acoustic conditions starts with a similar, general introductory statement requiring that buildings shall have satisfactory acoustic conditions in terms of health and comfort, considering the use.

4 ACOUSTIC CRITERIA FOR HOSPITALS – NORDIC COUNTRIES

Since the task was to find optimized, recommended acoustic limit values for hospitals (including other healthcare facilities) in Denmark, considering the regulations in the other Nordic countries, a comparison of the regulatory limit values [1-5] was made for various room types in hospitals. However, to get a wider perspective on quality levels in FI, IS, NO, SE, limit values for classes A-D and regulations have been tabulated for a typical hospital bedroom, which is a basic room type in such buildings and considered useful as a starting point for comparison.

In the below Tables 3-7 are found acoustic quality class criteria and regulations for normal hospital bedrooms. The limit values concern airborne and impact sound insulation, façade sound insulation, service equipment noise and reverberation time. For further details, see explanations in the tables. Class denotations A / B / C / D are indicated in descending order, i.e. the best class first.

By comparing the criteria in the Nordic countries for normal hospital bedrooms, it was found that the basic Danish recommendations, see e.g. the DK rows in tables 3-7, generally speaking were quite close to the corresponding criteria in the other countries, although closest to those from NO and IS. It was concluded that the basic Danish recommendations for *hospital bedrooms* could be kept and that a proposal for several other acoustic criteria could be developed based on the experience from the other Nordic countries. For airborne sound insulation between treatment and consultation rooms, it was decided to propose the present basic recommendation in DK [1] to be increased by 4 dB to $R'_w \geq 48$ dB to match the criteria in the other countries and to have more flexible room uses.

Table 3 – Acoustic regulations and classification – HOSPITAL bedrooms – Airborne sound insulation.

Nordic countries – Airborne sound insulation in HOSPITAL bedrooms ⁽¹⁾ – Quality levels & regulations – April 2018						
Country & reference	Rooms ⁽²⁾	Class A [dB]	Class B [dB]	Class C [dB]	Class D [dB]	Acoustic regulations
DK N/A	Between Corridor	N/A	N/A	N/A	N/A	None. Recommendation [1]: $R'_w \geq 48$ dB None. No recommendations.
FI [20]	Between Corridor	$R'_w \geq 52$ $R'_w \geq 39$	$R'_w \geq 52$ $R'_w \geq 39$	$R'_w \geq 48$ $R'_w \geq 34$	= npd	No specific regulations. [20] applied as guideline. New guideline related to [2] is under preparation.
IS [21]	Between Corridor	$R'_w \geq 52$ $R'_w \geq 45$	$R'_w \geq 50$ $R'_w \geq 40$	$R'_w \geq 48$ $R'_w \geq 35$	$R'_w \geq 45$ $R'_w \geq 30$	Building regulations [3] refer to Class C in [21].
NO [22]	Between Corridor	$R'_w \geq 52$ $R'_w \geq 44$	$R'_w \geq 50$ $R'_w \geq 39$	$R'_w \geq 48$ $R'_w \geq 34$	$R'_w \geq 45$ $R'_w \geq 30$	Building regulations [4] refer to Class C in [22].
SE [24]	Between Corridor	$R'_w \geq 52$ $R'_w \geq 40$	$R'_w \geq 48$ $R'_w \geq 35$	$R'_w \geq 44$ $R'_w \geq 30$	$R'_w \geq 40$ $R'_w \geq 30$	Building regulations [5] refer to Class C in [24].

(1) Overview information only. Detailed criteria and conditions are found in references.
(2) Between means between hospital bedrooms. Corridor means there is a door between the hospital bedroom and the corridor. If there is no door, stricter limits may apply.

Table 4 – Acoustic regulations and classification – HOSPITAL bedrooms – Impact sound insulation.

Nordic countries – Impact sound insulation in HOSPITAL bedrooms ⁽¹⁾ – Quality levels & regulations – April 2018						
Country & reference	Exposure ⁽²⁾	Class A [dB]	Class B [dB]	Class C [dB]	Class D [dB]	Acoustic regulations
DK N/A	Low impact High impact	N/A	N/A	N/A	N/A	None. Recommendation [1]: $L'_{n,w} \leq 58$ dB None. Recommendation [1]: $L'_{n,w} \leq 58$ dB
FI [20]	Low impact High impact	$L'_{n,w} \leq 63$ $L'_{n,w} \leq 63$	$L'_{n,w} \leq 63$ $L'_{n,w} \leq 63$	$L'_{n,w} \leq 63$ $L'_{n,w} \leq 63$	= npd	No specific regulations. [20] applied as guideline. New guideline related to [2] is under preparation.
IS [21]	Low impact High impact	$L'_{n,w} \leq 53$ $L'_{n,w} \leq 53$	$L'_{n,w} \leq 55$ $L'_{n,w} \leq 55$	$L'_{n,w} \leq 58$ $L'_{n,w} \leq 58$	$L'_{n,w} \leq 63$ $L'_{n,w} \leq 63$	Building regulations [3] refer to Class C in [21].
NO [22]	Low impact High impact	$L'_{n,w} \leq 53$ $L'_{n,w} \leq 53$	$L'_{n,w} \leq 55$ $L'_{n,w} \leq 55$	$L'_{n,w} \leq 58$ $L'_{n,w} \leq 58$	$L'_{n,w} \leq 63$ $L'_{n,w} \leq 63$	Building regulations [4] refer to Class C in [22].
SE [24]	Low impact High impact	$L'_{nT,w} \leq 60$ $L'_{nT,w} \leq 56$	$L'_{nT,w} \leq 64$ $L'_{nT,w} \leq 60$	$L'_{nT,w} \leq 68$ $L'_{nT,w} \leq 64$	– (= npd) $L'_{nT,w} \leq 68$	Building regulations [5] refer to Class C in [24].

(1) Overview information only. Detailed criteria and conditions are found in references.
(2) Low impact, e.g. from another hospital bedroom. High impact, e.g. from the corridor.

Table 5 – Acoustic regulations and classification – HOSPITAL bedrooms – Facade sound insulation.

Nordic countries – Traffic noise in HOSPITAL bedrooms ^{(1),(2)} – Quality levels & regulations – April 2018						
Country & reference	Descriptor	Class A [dB]	Class B [dB]	Class C [dB]	Class D [dB]	Acoustic regulations
DK N/A	N/A	N/A	N/A	N/A	N/A	None. Recommendation [1]: $L_{den}(\text{indoor})^{(3)} \leq 33$ dB
FI [20]	$L_{Aeq,07-22}(\text{indoor})$	≤ 30	≤ 30	≤ 35	= npd	No specific regulations. [20] applied as guideline. New guideline related to [2] is under preparation.
	$L_{Aeq,22-07}(\text{indoor})$	≤ 25	≤ 25	≤ 30	= npd	
IS [21]	$L_{p,Aeq,24h}(\text{indoor})$	≤ 20	≤ 25	≤ 30	≤ 35	Building regulations [3] refer to Class C in [21].
	$L_{p,Amax}(\text{indoor})$	≤ 35	≤ 40	≤ 45	≤ 50	
NO [22]	$L_{p,A,24h}(\text{indoor})$	≤ 20	≤ 25	≤ 30	≤ 35	Building regulations [4] refer to Class C in [22].
	$L_{p,AF,max,23-07}(\text{indoor})$	≤ 35	≤ 40	≤ 45	≤ 50	
SE [24]	$L_{pA,eq}(\text{indoor})$	≤ 26	≤ 30	≤ 30	≤ 35	Building regulations [5] refer to Class C in [24].
	$L_{pA,Fmax}(\text{indoor})$	≤ 41	≤ 45	≤ 45	≤ 50	

(1) Overview information only. Detailed criteria and conditions are found in the references.
(2) Furnished rooms.
(3) DK: Day 07-19 (default), Evening 19-22, Night 22-07. L_{den} is defined in END (2002).
The Danish Building Code refers to L_{den} as the only limit and valid for roads and railways separately.

Table 6 – Acoustic regulations and classification – HOSPITAL bedrooms – Service equipment noise.

Nordic countries – Service equipment noise in HOSPITAL bedrooms ^{(1),(2)} – Quality levels & regulations – April 2018						
Country & reference	Descriptor	Class A [dB]	Class B [dB]	Class C [dB]	Class D [dB]	Acoustic regulations
DK N/A	N/A	N/A	N/A	N/A	N/A	None. Recommendation [1]: $L_{A,eq} \leq 30$ dB
FI [20]	$L_{A,eq,T}$ $L_{A,max}$	≤ 24 ≤ 29	≤ 24 ≤ 29	≤ 28 ≤ 33	= npd = npd	No specific regulations. [20] applied as guideline. New guideline related to [2] is under preparation.
IS [21]	$L_{p,Aeq,T}$ $L_{p,Ceq,T}$	≤ 20 ≤ 40	≤ 25 ≤ 45	≤ 30 ≤ 50	≤ 35 ≤ 55	Building regulations [3] refer to Class C in [21].
NO [22]	$L_{p,A,T}$ $L_{p,AF,max}$	≤ 20 ≤ 22	≤ 25 ≤ 27	≤ 28 ≤ 30	≤ 33 ≤ 35	Building regulations [4] refer to Class C in [22].
SE [24]	L_{pA} L_{pC}	≤ 26 ≤ 46	≤ 30 ≤ 50	≤ 30 ≤ 50	≤ 30 - (= npd)	Building regulations [5] refer to Class C in [24].

(1) Overview information only. Detailed criteria and conditions are found in references.
(2) Furnished rooms.

Table 7 – Acoustic regulations and classification – HOSPITAL bedrooms – Reverberation time.

Nordic countries – Reverberation time in HOSPITAL bedrooms ^{(1),(2)} – Quality levels & regulations – April 2018						
Country & reference	Descriptor ⁽³⁾	Class A [s]	Class B [s]	Class C [s]	Class D [s]	Acoustic regulations
DK N/A	N/A	N/A	N/A	N/A	N/A	None. Recommendation [1]: $T \leq 0.6$ s
FI [20]	T	≤ 0.6	≤ 0.6	≤ 0.8	= npd	No specific regulations. [20] applied as guideline. New guideline related to [2] is under preparation.
IS [21]	T	≤ 0.5	≤ 0.5	≤ 0.6	≤ 0.8	Building regulations [3] refer to Class C in [21].
NO [22]	T	≤ 0.4	≤ 0.5	≤ 0.6	≤ 0.8	Building regulations [4] refer to Class C in [22].
SE [24]	T_{20}	≤ 0.5	≤ 0.6	≤ 0.6	- (= npd)	Building regulations [5] refer to Class C in [24].

(1) Overview information only. Detailed criteria and conditions are found in references.
(2) Furnished rooms.
(3) Freq. range 125-4000 Hz 1/1 octave bands. For Sweden and Finland target values. For details, see references.

Descriptors applied for airborne and impact sound insulation between hospital bedrooms are the same in the five Nordic countries, except for impact sound in Sweden. However, for indoor traffic noise and service equipment noise, all five Nordic countries apply descriptors being different, and while DK in [1] has one criterion for traffic and one for equipment, the other Nordic countries have two for each. – For further differences between the countries, see Tables 2-7.

For several other room types like meeting rooms, corridors, receptions etc. a similar process was applied, and a proposal has been made aiming at discussing, finalizing and publishing in DK the full set of acoustic recommendations for hospitals and other healthcare facilities. – For a few room types like e.g. auditoria and canteens differing significantly in shapes and sizes, relevant limit values must be made for each project. Likewise, specific limit values must be decided for psychiatric hospital rooms, for the noisy MR-scanning rooms and for sound insulation against helicopter noise. For open-plan offices in hospitals will be referred to the recommendations in the guideline for offices.

5 SUMMARY, CONCLUSIONS AND SUGGESTIONS

A proposal for acoustic recommendations for hospitals (and offices, see [6]) has been made based on comparative studies of criteria from the other Nordic countries having relatively small differences in limit values, at least when comparing to other parts of Europe (and the world). The purpose is implementation in the acoustic guideline to the Danish building regulations [1].

The proposed basic recommendations for hospital bedrooms, treatment and consultation rooms are: Airborne sound insulation between the rooms $R'_{w} \geq 48$ dB; Impact sound level $L'_{n,w} \leq 58$ dB

from other rooms; Noise from traffic $L_{\text{den}}(\text{indoor}) \leq 33$ dB; Service equipment noise $L_{A,\text{eq}} \leq 30$ dB; Reverberation time $T \leq 0.6$ s (125-4000 Hz). Limit values apply to furnished rooms. Compared to now [1], it is thus proposed to increase the sound insulation limit for treatment and consultation rooms with 4 dB to $R'_w \geq 48$ dB to obtain more privacy and more flexibility in room use.

The full proposal with acoustic recommendations for hospitals includes 33 limit values and a request for project dependent limit values for certain rooms like e.g. auditoria, canteens, psychiatric hospital rooms, the noisy MR-scanning rooms and for sound insulation against helicopter noise. A final review of the proposal will be made in the autumn of 2018, and implementation is expected in January 2019.

Related to acoustics in hospital buildings, a number of suggestions can be made based on the experience from the comparative studies of acoustic criteria for hospitals in various regulations, guidelines, acoustic classification schemes from the Nordic countries and other countries and a brief look at “Green building” certification systems and indoor climate standards:

- A Nordic dialogue and cooperation about optimizing/harmonizing descriptors for service equipment noise and indoor traffic noise limits - also useful for other building categories than hospitals.
- For canteens in hospitals, acoustic limit values should be prepared, e.g. based on findings in [37]. Such limits would also be useful for e.g. schools, office buildings, hotels etc. as well as restaurants.
- Green building certifications for hospitals are – as for office buildings and housing – increasing, and the performances included and ranking are highly relevant. However, a high number of very different “Green building” certification schemes exists, and it is difficult for clients and consultants to distinguish, cf. [38]. Points are shared between several competing performances, implying that acoustics is just one of many. Acoustic criteria in the schemes and benefits should be clearer, so it is understood that a high total score does not necessarily mean high-quality acoustic conditions.
- According to experience and literature, cf. e.g. [39] and [40], hospitals are noisy, influencing adversely the patients’ recovery and the conditions for the staff. Sources are, among many others, alarms, medical equipment, voices, footsteps, ventilation. Improving the physical environment, including acoustics, provides better conditions for both staff and patients. Some of the sources are related to the building and thus to acoustic criteria applied. Furthermore, it is important to be aware of acoustic characteristics for medical equipment and to discuss and clarify acoustic etiquette for the staff and the patients.

An important topic is also the whole structure of building codes and related documents. In most countries, it is very difficult to get a complete overview of acoustic regulations, guidelines and recommendations due to a complex variety of documents published by authorities, institutes, councils, standardization organizations and various other organizations and most often with no joint document linking those documents together. However, that was actually done in France in 2017, cf. [41] with a guide to the French acoustic regulations for buildings. The same is needed in many other countries with a complex pile of relevant acoustic documents. Another way would have been – in due time – to include all acoustic limit values in one document as in Norway, cf. [22].

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